# A STUDY OF SEAM GAS DRAINAGE IN QUEENSLAND

By
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## ABSTRACT

The gas drainage characteristics of two seams, the Bowen at Bowen No. 2 Colliery, Collinsville, and the Gemini at Leichhardt Colliery, Blackwater, are assessed. Single borehole tests and drainage panels were studied by underground monitoring of pressures and gas flows. Permeability was found to be effected by cleat to an order of magnitude. Other structural features are shown to be important. In this context, the need for delineation of no-flow zone locations in boreholes is shown to be of great importance where in-seam pre-drainage is being used for outburst control. Water in the seams strongly influences permeability causing gas flows to fluctuate with time. Use is made of modified reservoir engineering techniques to analyse the drainage characteristics of seams.

## INTRODUCTION

The paper covers studies of gas drainability at Bowen No. 2 Colliery, Collinsville and Leichhardt Colliery, Blackwater. It covers the material budget needed to analyse the effectiveness of gas drainage, techniques used to establish this, and the factors effecting drainage. Not only has drainage from boreholes been examined, but also the drainage into mine openings. The drainage studies have been conducted as part of a larger outburst research program being conducted by Australian Coal Industry Research Laboratories Ltd. (ACIRL) with funding from the Department of National Development & Energy.

## GEOLOGY

Both mines where studies have been carried out are in the Bowen Basin, Queensland.

Leichhardt Colliery is at approximately 400 m depth and is mining the Gemini seam of 6 m thickness. Approximately 35 m above this is the 2.5 m thick Aries Seam. The Gemini seam coal has a dominant cleat in a NE - SW direction. Butt cleating is far less marked.

The coal is wet and has a seam gas composition of approximately 95% methane and 5% carbon dioxide. The coal is coking coal of low ash content and rank of approximately 1.24% maximum vitrinite reflectance.

Bowen No. 2 Colliery is at the northernmost end of the Basin, mining the Bowen seam which dips to the south. The deepest part of the mine, 70 Level (70 L), where the gas drainage study was conducted is at approximately 300 m depth. In 70 L the seam is approximately 7 m thick with a stone lense of typical thickness 0.5 to 1 metre, 4 metres from the roof. Only the coal above the lense is mined. The coal has a predominant cleat but is less marked than that at Leichhardt and more butt cleats exist.

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The coal is wet and the seam gas is of predominantly igneous origin (Gould 1980). The composition varies around the mine but is virtually 100% carbon dioxide in 70 L. The coal is of variable rank throughout the seam due possibly to hot fluids causing localised coking (Rogis & Williams, personal communication). The rank variation measured by maximum vitrinite reflectance was 1.10% to 1.31% at 70 L.

## DRAINAGE STUDY METHODS

Any study of gas drainage involves the comparison of the initial gas content with the content after drainage for a period. Alternatively gas content measurement may be replaced by gas pressure measurement by the use of a sorption isotherm of seam gas on the coal. The rate of drainage is dependent primarily on permeability. To measure this some tests must be carried out over a period of time.

### ORIGINAL GAS CONTENT

Gas exists in coal in pore space, in solution in seam water and in sorption on the coal. The gas content is limited by two factors:

(a) The storage capacity of the coal.

(b) The gas available for storage.

The storage capacity of the coal is controlled by the pressure that can be developed before leakage of gas occurs. At a certain gas pressure the storage is related to the storage capacity. The most important storage mechanism is sorption. An example of a sorption isotherm is given in Figure 1. (The laboratory techniques and equipment for determining sorption isotherms is described by Gray & Truong (1982).)

This arbitrarily sets gas content at zero for one atmosphere pressure. All volumes stored below atmospheric pressure are labelled negative for clarity, thus enabling direct comparisons between core desorption to atmospheric pressure and sorption isotherm gas contents.

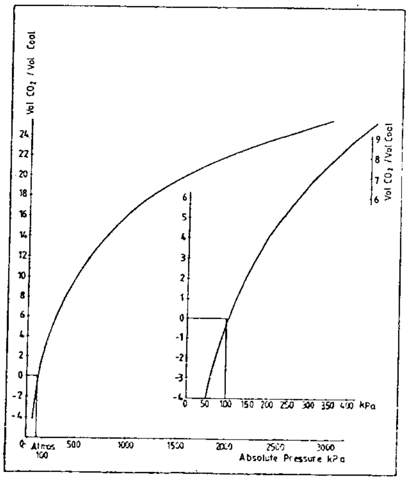

Fig. 1 - Combined sorption isotherm for Bowen No. 2 Colliary 70L, 3H and 69L, 2H.

The gas available for storage is dependent on the gas produced by coalification and/or igneous sources minus that which has escaped through leakage.

If a seam is fully water saturated then higher water pressures can exist in the seam than the equilibrium pressure indicated by a sorption isotherm.

This means that the gas content in a saturated coal is locked into sorption and water pressures can rise without any change in gas content.

To measure the gas content of a coal two methods presently exist. The first is a direct core desorption test where core is taken and placed in a container and a time record of gas released is made (McCulloch 1976). Variations of the test exist but all require some back analysis to determine lost gas during the period between coring and sealing within a canister. The second method involves the measurement of seam fluid pressure and its comparison with a sorption isotherm determined in the laboratory. While seam fluid pressure can be measured readily the determination of whether this is just a water pressure unrelated to gas content or whether the seam fluid pressure is the gas pressure presents some difficulties. Some form of pressure bleed off until gas rather then just water is released is required to establish the gas pressure associated with the level of seam gas content. The main advantage of pressure monitoring is that it can be used to give a continuous record which in most cases can be directly related to gas content.

## TYPES OF DRAINAGE TEST

### Long term tests

Two basic long term drainage tests exist. The first involves the material budget: 'initial gas in place - gas produced = gas left'. The second involves continual monitoring of gas in situ. This procedure is difficult by direct methods as core removal for gas content measurement changes the geometry of the drainage pattern because it requires a hole to be bored. The alternative is to monitor pressure directly by the use of permanent pressure sensors, relating this to gas content if desired.

The material budget. The material budget method requires that the initial gas content is found by one of the methods described. This is most practically done underground by pressure measurement periodically at the end of a drainage borehole using hydraulic packers to seal the borehole end at various depths of drilling. If gas content is being found from the surface then core type desorption tests are the most simple, though a downhole fluid pressure measurement/gas pressure measurement rig is under development by Australian Coal Industry Research Laboratories Ltd. (ACIRL) for use to depths of 500 m.

Once the gas content has been determined the quantity of gas drained must be measured. This presents some problems because drainage is not uniform. The initial pressure and gas content is likely to vary with depth from the ribside causing a variation in drainage with depth. More importantly drainage varies along the length of the borehole, regardless of proximity to the ribside, some areas showing high flow and others low. To be able to examine which areas of the borehole are degassing, up-hole measurements of flow at different positions need to be made.

To do this an incremental flow test is conducted by sealing the borehole at various depths with a packer on the end of a conduit string and measuring the total flow from behind the packer. This enables a picture of cumulative flow versus depth to be built up. The slope of this is the flow/unit length. Repeated incremental flow measurement can be used to gain an understanding of flow change with time. The flow/unit length can be integrated with time to provide the cumulative quantity drained. Once this has been done the material budget equation can be solved.

gas left = initial gas in place - gas produced

Discrepancies from the material budget may occur. Excessive gas volume prediction is an indication of several possibilities:

a) An underestimation of initial gas content. This can be caused by excessive gas loss in core desorption tests not corrected for in gas loss calculations. If sorption curves are used with pressure measurement a leaking packer or other seal failure can cause a low pressure to be measured and hence a low gas content to be estimated.

b) A seam thickening. This will increase the volume of coal that can hold gas.

c) Ineffective cut-offs. The artificial boundaries to the area being considered, usually boreholes, may not be effective. Seam inhomogeneity and uncertain borehole position in seam are the most likely causes of leaky cut-offs.

d) Gas make from seam roof or floor.

Low gas volume prediction is less easy to identify because of the difficulty in distinguishing it from low permeability. Pressure measured on a shut-in test of a borehole will indicate whether gas is still present. Actual low gas volumes may be due to:

a) Overestimation of gas content. The most likely source of error is in the use of sorption isotherms and pressure measurement. This occurs if the pressure measured is that of water pressure because the seam is saturated, and the gas content would have been reached on the sorption isotherm at a lower pressure.

b) Seam thinning.

c) Flow through ribsides not being accounted for.

Continual monitoring. Continual pressure monitoring tests involve the installation of permanent pressure sensors around some drainage configuration. The test drainage pattern may be any group of boreholes or mine roadways. If a drainage borehole pattern is to be used then the most useful is a centrally placed pressure sensor flanked by two pairs of drainage boreholes as shown in Figure 2. This configuration approximates to a drainage panel at the borehole spacing. The outer boreholes act as cutoffs to lateral flow while the inner two should behave as part of an evenly spaced panel. The borehole spacing needs to be less than the depth from the pressure sensors otherwise ribside drainage is likely to mask the effects of the boreholes. The pressure sensors most satisfactorily used are grouted-in single or multiple point pressure sensors as described in Gray & Truong (1982).

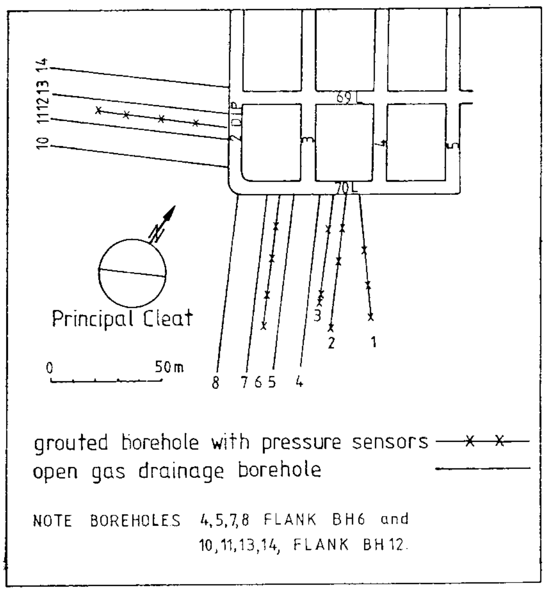

Fig. 2 - Collinsville 70L gas drainage test. Note: Boreholes 4, 5, 7, 8 flank Borehole 6 & Boreholes 10, 11, 13, 14 Flank Borehole 12.

Short term tests.

Many variations on the theme of drill stem tests involving shutting in a producing borehole can be used. These are described in Gray & Truong (1982). They all involve significantly more interpretation than the long term tests described. They also cover a smaller zone around a borehole. The main advantage of this type of test is speed and its use in a single borehole. The main complication is the interpretation in the present of two flow phases, water and gas.

## DRAINAGE INTO HEADINGS

Several studies have been undertaken which involve measuring the pressure distribution around a panel or heading end. These have been useful in showing the effects of anisotropy in permeability due to cleating. These studies are presented below.

## ALPINE HEADING, D NORTH INTAKES, LEICHHARDT COLLIERY

This was the initial test site for grouted-in pressure sensors. The site is shown in Figure 3. Four sensor points were successfully grouted in. These tended to show a pressure distribution that suggested along-cleat drainage forming a degassed "shadow zone". A triple packer was subsequently installed and results from it tended to confirm this. The initial pressures are shown in Figure 4. The grouted-in pressure sensors have been subsequently monitored for some years. Some drainage has been observed but the most interesting feature has been the sudden rise in pressure after points in borehole 6 and borehole 4, shown in Figure 5. The closeness of the pressure curves following the change appears to indicate some form of cross linkage. This may be the result of fracturing during stress redistribution bump.

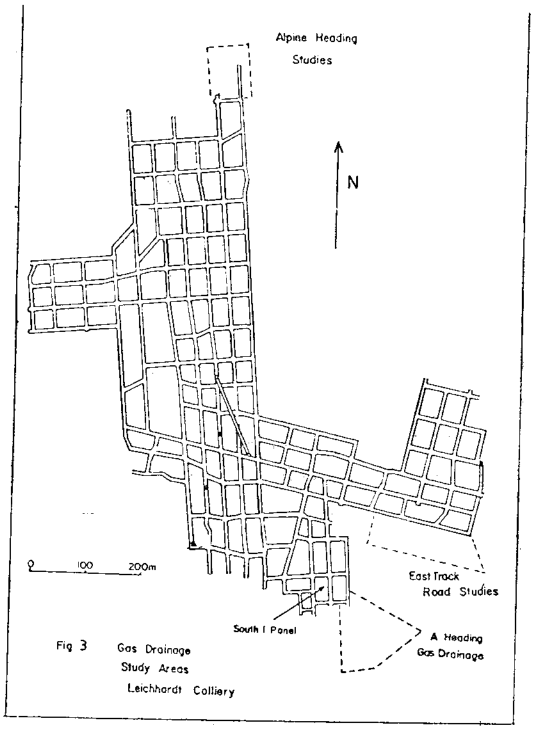

Fig. 3

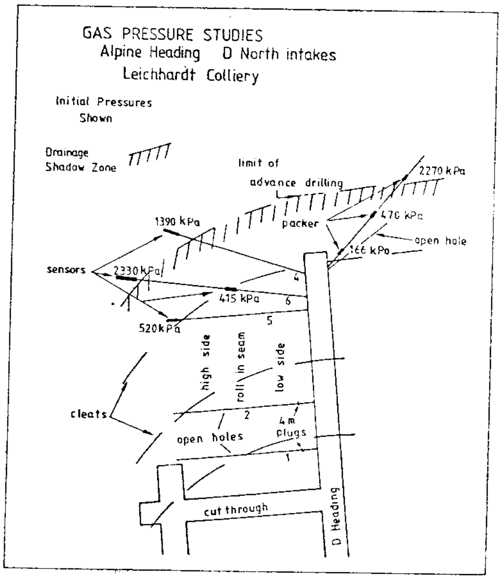

Fig. 4

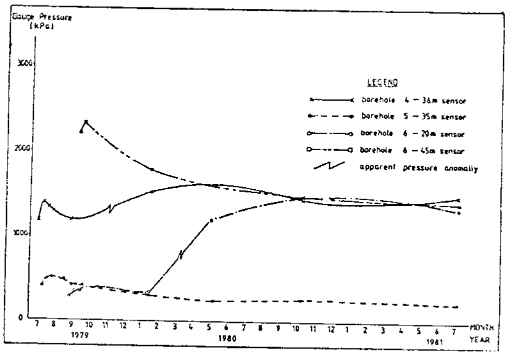

Fig. 5 – Time vs. pressure
Boreholes Alpine heading Leichhardt Colliery

Pressure distributions measured around one of the first outburst sites in B heading are shown in Figure 6. Once again these show a marked lower pressure along the cleat compared with across the cleat. This closely ties with the formation of the outburst core in the high pressure cross-cleat side of the heading.

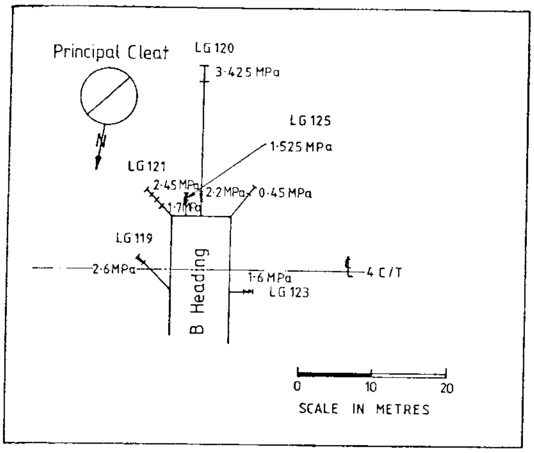

Fig. 6 – Summary stable gas pressures
Face B Heading – 1 South Panel

## EAST TRACK ROAD, D HEADING EAST, LEICHHARDT COLLIERY

Four boreholes were drilled into solid coal off the eastern end of the roadway. A pressure distribution was gained from this using incremental drilling and hydraulic packers. This distribution is shown in Figure 7. Once again it shows a strong trend of along-cleat drainage. A differential compaction fault due to a washout appears to have enhanced drainage into the roadway to some degree. Its detailed effects on drainage will be discussed later in the section on drainage into boreholes.

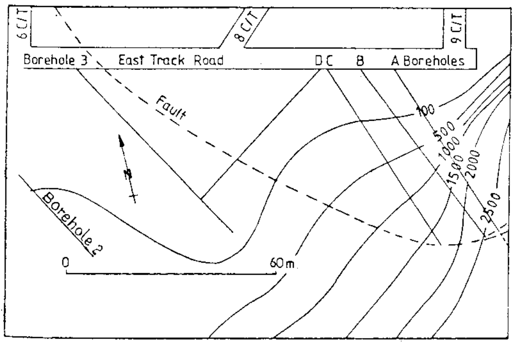

Fig. 7 – Gas Pressure Contours
Leichhardt Colliery Experiment

## ONE SOUTH PANEL, LEICHHARDT COLLIERY

One South Panel has been developed as a shotfired panel, previous development being by continuous miner. It is the first panel developed since the fatal outburst of 1-12-78. Because of concern over further outbursting, a pressure monitoring program was undertaken by the colliery. This involved drilling ahead of the panel and measuring pressure using single hydraulic packers. While these were found to have some leakage problems they enabled a reasonably clear picture of seam pressures to emerge. Figure 8 shows the pressures measured some distance ahead of the mining advance and their relation to the cleat. The pressure contours show a very quick rise in pressure beyond the previously existing East and old South panels. The two older panels had been driven five and six years before One South Panel. Some indication of cross-cleat drainage is apparent but mostly drainage has occurred along the cleat. It is worth noting that outbursts occurred at Leichhardt in One South Panel along the line of 2.5 MPa pressure in A, B and C headings. In some cases the pressures slightly lower than 2.5 MPa existed close to the face in outburst conditions.

## 70 LEVEL DRAINAGE – BOWEN No. 2 COLLIERY, COLLINSVILLE

A drainage program was carried out in the dips area of Bowen No. 2 Colliery, Collinsville. This involved flanking pressure sensors with drainage boreholes as shown in Figure 2. The program was carried out in both along-cleat and cross-cleat directions. The pressure distributions into solids from the ribsides were substantially different for the along- and cross-cleat situations despite similar times between mining and drilling investigation. In the case of the cleat not draining into the roadway, a peak gauge pressure of approximately 1330 kPa was measured at 30 m depth. Where the cleat could drain into the roadway, maximum

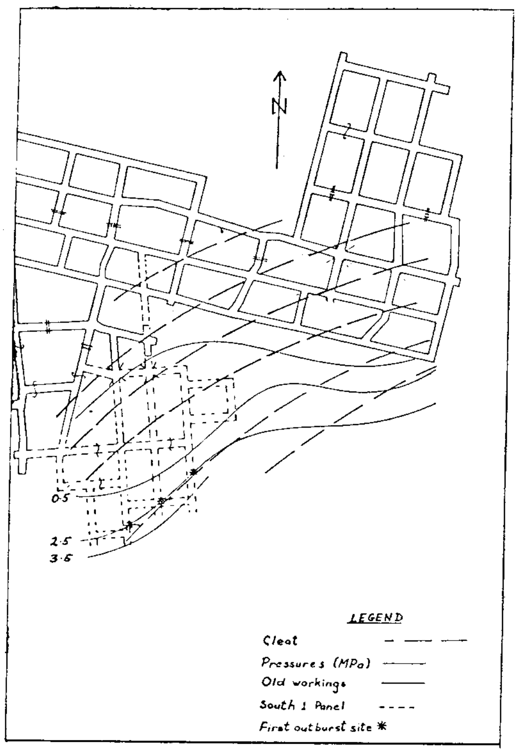

Fig. 8 - Fluid pressure contours
South 1 panel Leichhardt Colliery

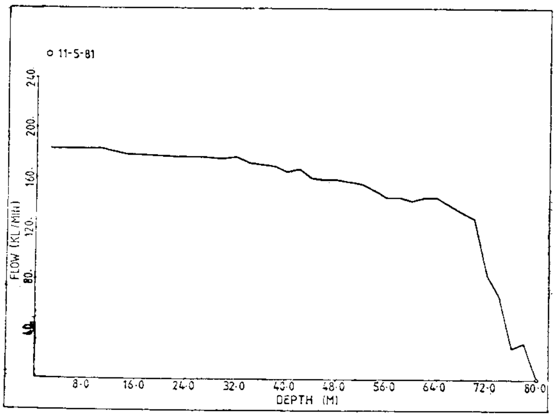

Fig. 9 - Cumulative incremental flow
Borehole 14, Collinsville

pressure recorded at 60 m depth was 280 kPa. Flow trends from the boreholes confirmed this. The cumulative incremental flow curve for borehole 14 (Figure 9) shows very low increments of flow to 64 m depth beyond which inflow rises quickly.

## DRAINAGE INTO BOREHOLES

Several tests have been carried out to test seam drainage using in-seam boreholes. Both material budget and continual pressure monitoring have been used.

### EAST TRACK ROAD, LEICHHARDT COLLIERY

As described in the sections on drainage into roadways, four boreholes, three cross-cleat and one along-cleat were drilled from the East Track Road. Pressures were measured using hydraulic packers. The boreholes were then left to drain into the atmosphere and the flow monitored by incremental flow testing techniques so that a material budget could be obtained along the borehole length. The flow per unit length versus time at various depths for boreholes B and C are shown in Figures 10 and 11. The general trend is for a flow rise and decay with increasing depth. The decay is most marked in the case of borehole B because of a partial cut-off effect from boreholes A and C. The efficiency of the cut-offs is not good as flow from borehole B exceeds tenfold the expected gas content in the block measured from the midpoint between boreholes A and B, and B and C. This is shown on the cumulative volume released curve for borehole B shown in Figure 12.

This cut-off failure is not surprising as the boreholes are not parallel in plan. The separation between borehole A and B varies from 3.5 to 8 m based on borehole collar orientations. Also the boreholes are placed in a 6 m thick seam and their horizon in the seam is unknown. Flow is not expected to be contributed from the roof or floor as roof and floor holes have given no gas emission. The boreholes may be considered to act as a borehole group draining a semi-infinite solid. The rise and decay trend of gas flow is typical of two phase simultaneous water and gas flow as shown by Kissell (1975) and the author's own simulation.

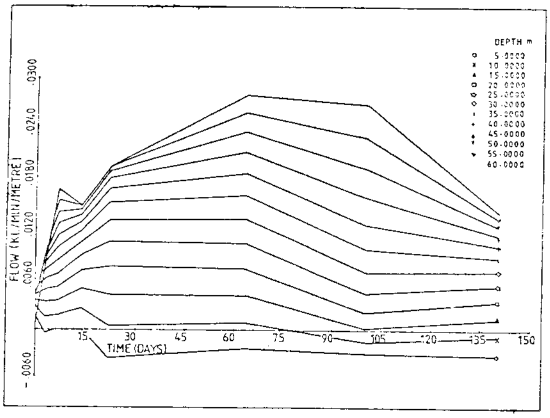

Fig. 10 - Flow/unit length at depth vs. time.
Borehole B East track road Leichhardt Colliery

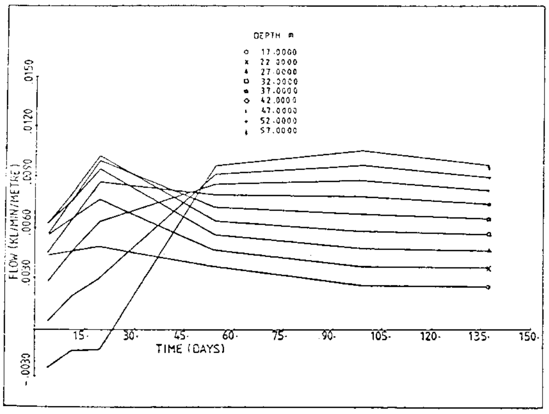

Fig. 11 - Flow/unit length at depth vs. time
Borehole C
East track road Leichhardt Colliery

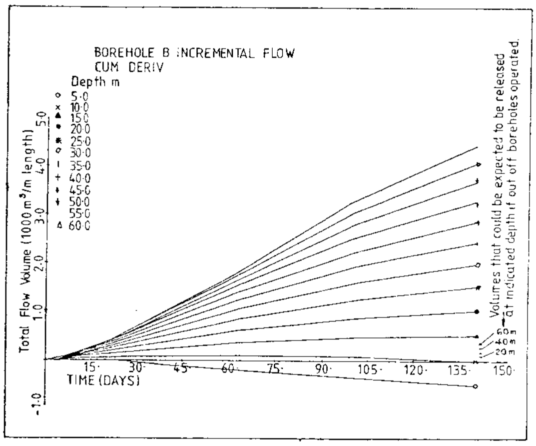

Fig. 12

It is possible to speculate that the higher flows from borehole B compared with boreholes A and C after a period of initial drainage are due to partial dewatering by the latter, increasing permeability. The initial flows of all boreholes were similar.

Another effect associated with water has been found. The boreholes A, B and C were all down dip and naturally filled with water through which the gas bubbled. These boreholes had to be purged of water before successful incremental flow measurements could be made. The total borehole flow typically increased 10 - 15% after purging. It is not known whether this is a long term effect. The most logical explanation is that a reduction of permeability to gas occurs around a borehole because of the presence of water.

To some degree structure of the coal can be defined by the incremental flow tests. It is known that core permeability is less than five millidarcies (mD) for cores of Leichhardt coal; however bulk permeabilities indicated are in the order of 200 mD for drainage along the cleat. This indicates a strong influence of cleat permeability over that of the solids. This cleat permeability varies fairly widely.

The raw incremental flow data on boreholes B & C shown in Figure 13 show significant inhomogeneity. Borehole D which was drilled along cleat shows virtually no flow with the exception of one region. This lies on the expected path of a fault. It is therefore considered that the fault is highly permeable despite its throw of 20 cm. It has also demonstrated the use of incremental flow testing in locating structures. The incremental flows for borehole D are shown in Figure 14.

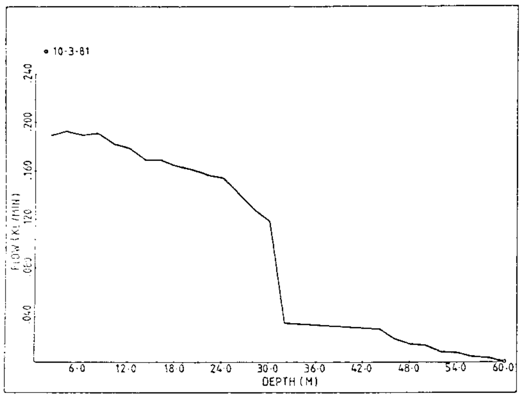

Fig. 13 - Cumulative incremental flow
Borehole C, East track road
Leichhardt Colliery

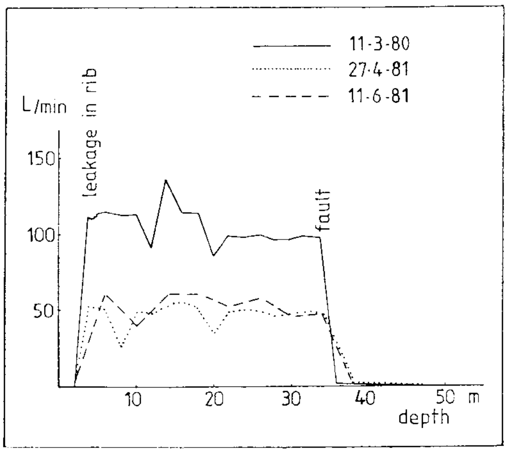

Fig. 14 - Cumulative incremental flow curves Borehole D, East track road Leichhardt Colliery

## 70 LEVEL DRAINAGE, BOWEN No. 2 COLLIERY, COLLINSVILLE

### Original gas content

Core desorption testing - The mine has carried out an extensive program of core desorption testing to determine gas contents. These have been corrected for lost gas by the use of an initial volume desorbed Vs log time plot which is extrapolated back to the time when desorption is expected to commence after drilling. The latter is determined as being when core gas pressure is expected to exceed hydrostatic pressure in the borehole, (J. Rogis & Williams Personal Communication), during core retrieval.

The estimated gas content of the two closest boreholes C337 and C349 is 18.87 and 13.97 $m^3$/tonne on a dry ash free basis (daf). The average of these is 16.37 $m^3$/tonne (daf). The average gas content including ash is 12.93 $m^3$/tonne.

Pressure measurement and sorption curves - Pressure measurement in 70 L drilling has shown a virgin gas pressure of 1350 kPa gauge pressure. Using the data from six sorption tests it is possible to correlate this to seam gas content, using Figure 1 to correspond to 19.45 $m^3$gas/$m^3$ coal (approx 13.41 $m^3$/tonne). Using a mean sorption curve on a daf basis the gas content could be expected to be 16.4 $m^3$/tonne (daf) which is virtually identical to that from core desorption (16.37 $m^3$/tonne). This tends to confirm that the seam gauge pressure is about 1350 kPa gauge. On this basis the gas content is accepted as being 19.45 $m^3 CO_2/m^3$ coal for analysis purposes.

### Material budget

A comparison between gas contents calculated from a material budget and from continual pressure measurement combined with sorption isotherms is presented which refers specifically to the cross-cleat borehole group in Bowen No. 2 Colliery, 70 Level as shown by boreholes 4, 5, 6, 7, and 8 in Figure 2. Borehole 6 was initially fitted with a triple hydraulic packer which was unsatisfactory and replaced by a grouted-in pressure sensor as the pressure monitoring system. Total flows from boreholes 4, 5, 7 and 8 were recorded over a year and two sets of incremental flow tests were carried out on each borehole.

Assuming that boreholes 4 and 8 acted as cut offs the flows from boreholes 5 and 7 will be similar to flows from an infinite drainage panel at that spacing. Half flows from boreholes 5 and 7 can therefore be expected to be supplied from the blocks flanked by those holes.

Taking full account of flow/unit length variations from average flow indicated by the slopes of incremental flow curves and the variations with time in the slopes of these incremental flow curves the total flows have been scaled to provide flow at depths of 15, 30, 45 and 60 m. These flows have been cumulatively integrated with time and subtracted from initial gas content in the block to provide an estimate of gas remaining. This is compared with gas quantity estimates using the appropriately located pressure sensor.

During periods when BH6 was opened it is assumed to behave similarly to the average of boreholes 5 and 7.

At 15 m depth initial pressures were too low because substantial ribside drainage had already occurred to carry out a meaningful material balance. At 60 m depth flow was approximately 50% in excess of what could be expected. This is initially surprising as the drainage boreholes extended 20 m beyond the pressure monitoring point specifically so that end drainage effect of solids would be avoided. Examination of Figure 15, the cumulative incremental flow curve for borehole 7, shows an area inbye of 64 m with negligible flow. Boreholes 4, 5 and 8 behave similarly reducing their effective length substantially and preventing an off cut effect. At depths of 30 and 45 m excellent correspondence between material balance and gas content by pressure measurement is obtained. Gas content has had to be referenced initially by pressure for the 30 m case at less than virgin because of some pre-drainage towards the ribside and also due to pressure loss in failing to seal borehole 6 adequately by the triple packer initially. After grouting, the comparison between gas contents is good. The 45 m case shows excellent correspondence from virgin content and pressure with slight deviation only occurring over the final time. This deviation corresponds to a slight pressure difference (30 - 78 kPa). Some difference must be expected as gas content based on a central pressure measurement between two drainage boreholes must be higher than that given by gas content from material budget as the latter is an average block pressure. The comparisons between material budget and pressure-sorption gas contents for 30 and 45 m are given in Figures 16 and 17 respectively.

The cause of the low flows inbye on boreholes 4 to 8 is not known. It is suspected that it may be due to the holes dipping and entering a strata of high ash and low permeability close to the floor.

## SORPTION AND MACERAL CONTENT

Within the restriction of only having performed six sorption tests on Collinsville coal a relation is tentatively proposed between rank, maceral contents and sorbed carbon dioxide content. The relation is between sorbed gas and the rank x vitrinite product. The rank value used is the percentage maximum vitrinite reflectance while vitrinite content is the proportion of vitrinite in the sample on an ash free basis. Sorption is measured in terms of volume sorbed on an ash free basis. The relation is shown in Figure 18 and suggests that higher rank vitrinite dominates sorption at over 1000 kPa absolute pressure while inertinite dominates sorption at over 1000 kPa absolute pressure while inertinite dominates below this. The actual relation could be expected to follow equation (1) -

$$S = aI + Vo + bRoV \qquad (1)$$

where

S = sorption at a pressure
I = inertinite proportion
Vo = a constant
Ro = Rank
V = Vitrinite content
a = a constant
b = a constant

if rank changes primarily effect the vitrinite.

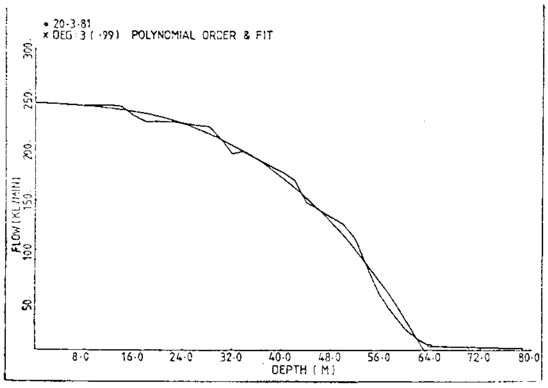

Fig. 15 - Borehole 7. Cumulative incremental flow with fitted polynomial showing low flow inbye.

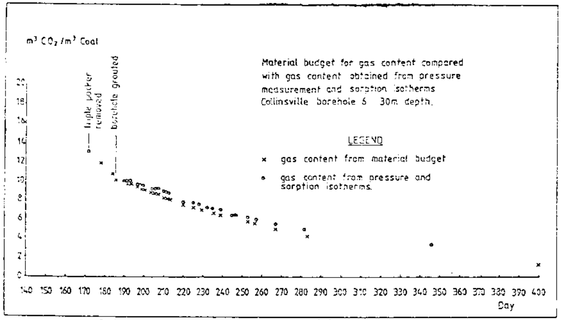

Fig. 16

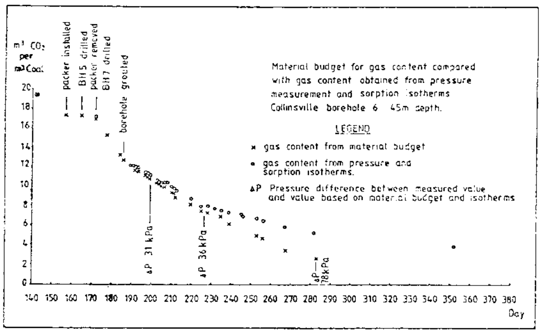

Fig. 17

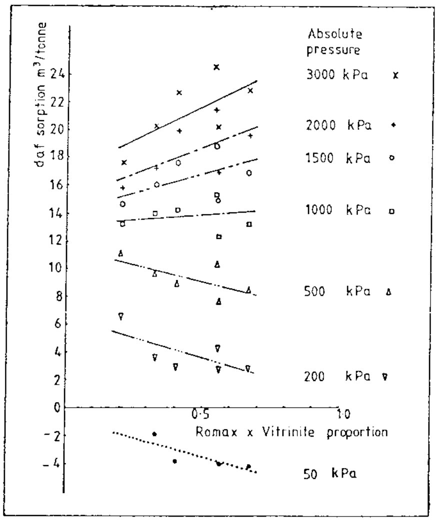

Fig. 18 - Relation between sorption on a dry ash free basis and the rank x vitrinite (mineral matter free basis) product $CO_2$ at 25°C
Ro max range 1.10 to 1.31%
Vitrinite range 18 - 56%

## CONCLUSIONS

The foundation of gas drainage studies, a material balance check, has been detailed in the paper. Without this, no concept of gas quantity or its drainage exists. The East Track Road study typifies an example where cutoff boreholes were ineffective as revealed by the material budget while the 70 Level example displays a good cut-off and understanding of gas movement. Once the material budget has been understood gas drainage studies can be extended to cover pressure decline curves and simulation.

The presence of water has been shown to be important in reducing seam permeability to gas. All drainage studies conducted should estimate water release quantities. Furthermore, tests for permeability, particularly short term pressure rise rate tests, should be conducted bearing in mind the permeability-reducing effects of water.

Inhomogeneity in seam gas drainage has been revealed by the use of incremental flow testing. Both high and low flow zones can be detected. Some incremental flow testing is essential in conducting a material budget investigation. Practically, particularly in outburst prone mines, the incremental flow test can be used to locate areas which are not degassing and are therefore potentially dangerous. Similarly faults or other high gas flow anomalies can be detected.

The cleat has a strong effect on permeability and any gas drainage test program or production exercise should be conducted in full knowledge of cleat direction.

Excellent comparisons of gas content between core desorption without an allowance for residual gas, and sorption isotherms have been found.

## ACKNOWLEDGEMENTS

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## DISCUSSION

J. DONALDSON (Miners Union): Did you say that a dangerous situation could exist in Collinsville?

I. GRAY (A.C.I.R.L.): No. It is well known that there have been outbursts in Collinsville and this is the reason for this work to anticipate and alleviate any incipient dangerous conditions. What was said was in that particular area - possibly not so serious. If there had been known dangerous conditions in Collinsville and the mine were not concerned about it the work described in the paper would not have been done. By contrast the mine is very well on the road to helping deal with those problems with its aggressive approach to dealing with problems.

J. DONALDSON: The content of the paper confirms the good research job done over the years up there.

R. KING (Bureau of Mines, U.S.A.): Regarding the last information on the macerals, the National Coal Board and also the U.S. Bureau of Mines are doing quite a bit of work on this.

I. GRAY: The N.C.B. reference on Firedamp Drainage is known here. Most of the published work seen has been done by Ettinger in the U.S.S.R. It would be interesting and useful to compare results and to see what developed.

R. KING: There has been quite a bit of work done. The Oil and Gas industry in U.S.A. have used vitrinite reflectance for years as a way of indicating whether the pay is on or not. It is what everyone has looked at as far as gas. To see if it is cheaper - at least an indirect method of determining gas content and so far the answers have not yet suggested any relationship or law.

I. GRAY: An excellent relation was obtained in terms of Collinsville's cores and the sorption pressure work. Enough to believe the investigations were useful.

K. NOACK (Westfalische Bergerwerkshafts) Are the values of the gas contents of Collinsville which are given in the paper on a dry and ash free basis to be read as desorbable or as total gas content?

I. GRAY: This is a difficult problem. The Europeans always refer to and to some degree the United States refer to desorbable and non-desorbable gas contents. This correlation has been found by direct field work. The gas content quoted is what can be measured in a sorption test rig. Unlike the gravimetric test of Lama this was a volumetric sorption test but basically it should do exactly the same thing. All of the sorption work described has been referenced to atmospheric pressure. There was no work into the vacuum range, that is just a shift of axes. There are some doubts about these non-desorbable and desorbable gas contents in the Australian context. Certainly the work done by the B.H.P. Oil and Gas Division on Leichhardt coal where they did normal core desorption and then ground the core afterwards showed absolutely no residual gas content.

C. JEGER MADIOT (CERCHAR, France): Regarding the problem of the decreasing of gas content, considering total instead of desorbable gas content does not matter. It should be a problem if the released gas content would be proportional to the initial content (which one?) and if the final content could not be expressed in terms of desorbable gas content (final partial pressure less than 1 atm). When measuring the desorption of gas in situ, it is noticed that the released gas content and therefore the residual content are not a percentage of the initial gas content; there is always a remaining stable desorbable gas content lying between 1.5-1.7 and 2.5 - 3.0 $m^3/t$. The reason of this final remaining desorbable gas content, independent from the initial content, is probably the necessary gas pressure higher than 1 atm remaining in the seams, which is necessary to induce the latest small flow of gas. The gas content which is released is the difference between the initial and the residual gas content. This difference does not depend on the method of measurement of the gas content, because the final content can be measured even as desorbable gas.

I. GRAY: The normal way though of establishing what the remaining gas content rather is is to grind the coal. Is that done in France? Is the coal ground to find the remaining gas content.

C. JEGER MADIOT: Yes

I. GRAY: In the case of the work described of comparing the two, grinding is unnecessary, because a field measured value is compared with sorption with field material budget. It is known that there is a remaining pressure in the seam. This is working by absolute gas contents on ground sorption samples.

B. HAM (M.I.M. Holdings): It was stated that there is a dependence on the cleat of the effectiveness of draining. Could the directional sensitivity of the cleat limit drainage effectively in one direction? Is there a wide range of angles that are still effective for drainage. Is it then best to turn panels off at say 45$^{o}$ and keep draining forward or drive perpendicular to the cleat with the holes at 45$^{o}$ and advance a larger area that way by drainage? Is there any feel for that sort of problem?

I. GRAY: With a dry hole in the Bowen Basin and a drainage rate not exceeding the gas production by coalification, it would drain the Bowen Basin. It's a matter of time. There is a permeability across the cleat and a permeability along the cleat and permeability which can be worked out mathematically in between, or by test depending on the particular approach to the problem. In a seam in which drainage along the cleat is exceedingly dominant then indeed the boreholes must cross that cleat. In a totally dominant along cleat drainage system then the effective borehole spacing would have to be treated as the distance between boreholes measured in an along cleat direction. Certainly in Collinsville's case in the dips where work was done, drainage would be faster into a heading being advanced than into boreholes drilled along the cleat. Each method must be examined on its merits. Also, in a P.R. of ACIRL, Gray has proposed a technique for establishing permeability tensors from cleat measurement. It is not proven. It's mathematically correct. It now requires the good services of John Shephard to do some cleat work and possibly some more drainage work to be done to compare the two and see how they go, but in terms of tests, an attempt should be made to pick which are the principal directions. In other words, which is the maximum permeability direction and which is the minimum permeability direction and to try to do the tests along each of those directions, which should be mutually perpendicular. The idea of this mathematical method is that a start can be made to choose these directions without having to drill umpteen holes around the angle. This work should save time so that people don't have to put in entire gas drainage panels to find out what to do. That is apart from the outburst side of the research which is a little bit separate.